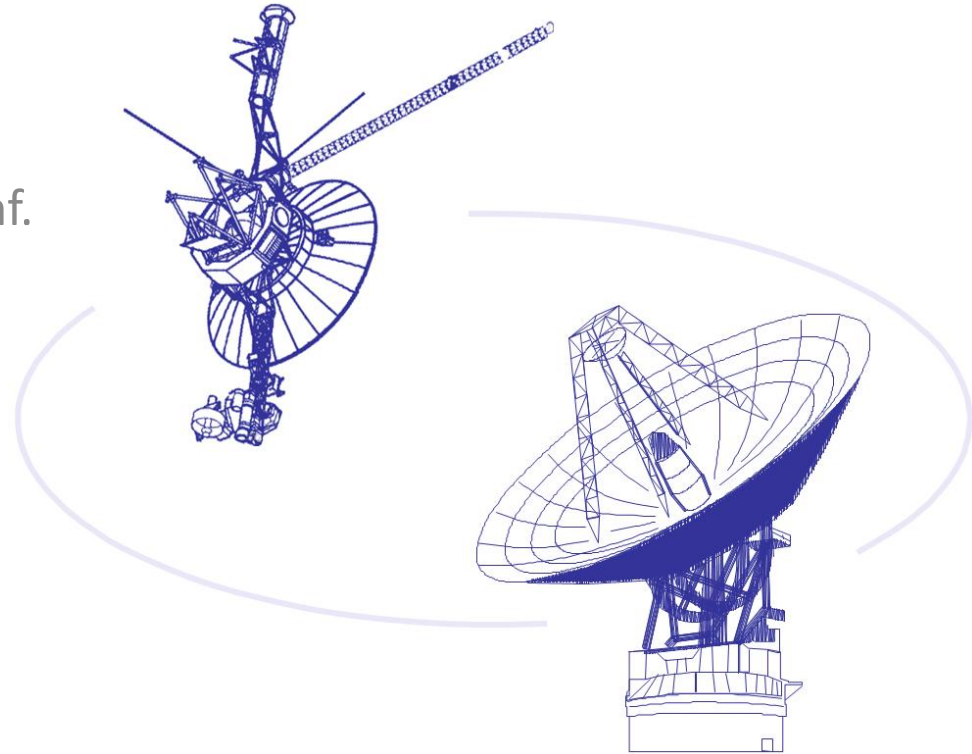


Development of Telecommunication Systems for EM-1 Interplanetary CubeSat Missions

2017 Interplanetary Small Satellite Conf.
San Jose, California, USA
1-2 May 2017

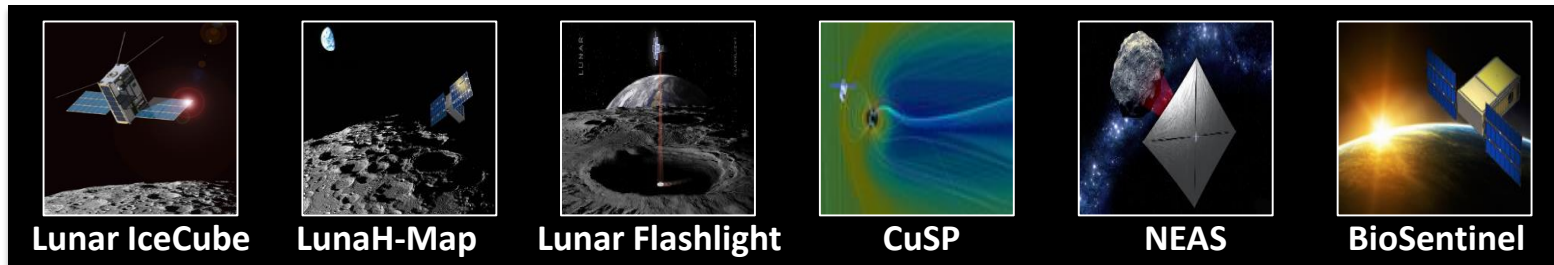


K. Angkasa, A. Babuscia, J. Baker, N. Chahat, M. Chase, F. Davarian, C. Duncan, T. Dobрева, S. Holmes,
M. Kobayashi, C. Lau, D. Lewis, A. Yarlagadda

Jet Propulsion Laboratory at the California Institute of Technology

Development of Telecommunication Systems for EM-1 Interplanetary CubeSat Missions

- Introduction to EM-1 CubeSat Missions
- 6 EM-1 CubeSats Using Iris



- Telecom Systems End-to-End
- Telecom Architecture & Development Challenges for Each Mission
- Telecom Architecture Summary
- Telecom Parameters Summary
- Closing Remarks

EM-1 CubeSat Missions



Launch Abort System

Orion

Interim Cryogenic
Propulsion Stage (ICPS)

Secondary Payload

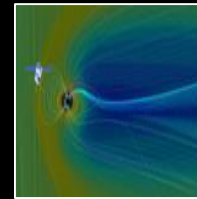
Launch Vehicle Stage Adapter

Core Stage

Solid Rocket Boosters



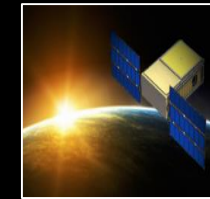
Lunar Flashlight, JPL



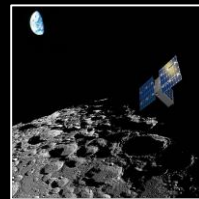
CuSP, SWRI



NEAS, MFSC



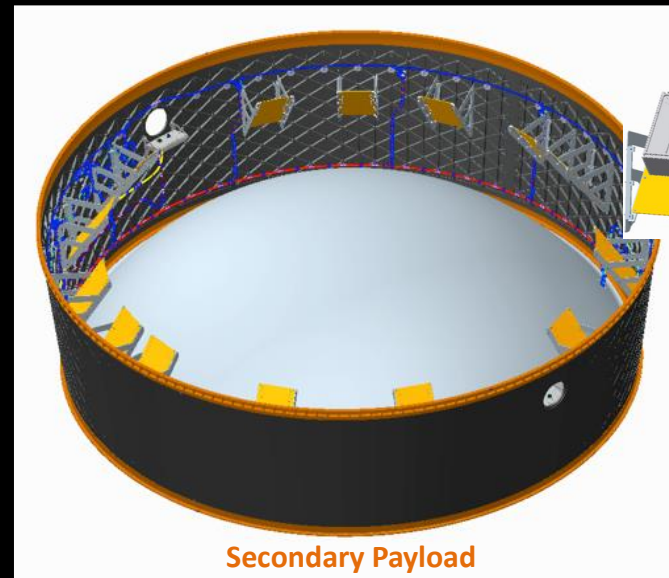
BioSentinel, AMES



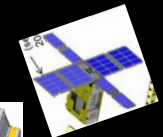
LunaH-Map, ASU



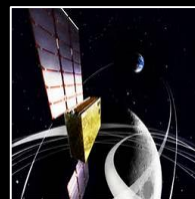
Lunar IceCube, MSU



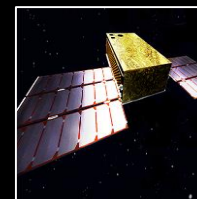
Secondary Payload



SkyFire, LM



OMOTENASHI, JAXA



EQUULEUS, JAXA



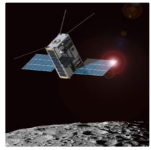
Centennial
Challenge



ArgoMoon, Argotec

— 6 missions using Iris Transponder

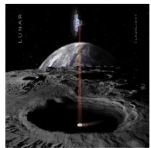
6 EM-1 CubeSat Missions Using Iris V2.1 Transponder



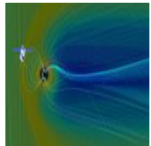
Lunar IceCube



LunaH-Map



Lunar Flashlight



CuSP

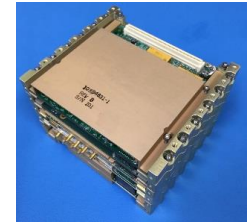


NEAS



BioSentinel

Telecom Hardware	Salient Features
Iris V2.1 Transponder	
Network Compatibility	DSN
Frequency Bands	X-band
UL X-Band Freq.	7.145 - 7.190 GHz; 7.190 - 7.235 (near Earth)
DL X-Band Freq.	8.400 - 8.450 GHz; 8.450 - 8.500 GHz (near Earth)
UL Command Rates	62.5 - 8k bps, PCM/PSK/PM
UL Subcarriers	16 kHz, Direct carrier modulation
DL Telemetry Rates	62.5 - 256k bps Turbo 1/2, 1/3, 1/6, Conv. 7-1/2, RS (255,223)
DL Subcarriers	25 kHz, Direct carrier modulation
Command/Telemetry	CCSDS 232.0-B-3 TC Space Data Link Protocol CCSDS 732.0-B-3 AOS Space Data Link Protocol
Iris Low Noise Amplifier (LNA)	2 RF paths, dedicated to 2 antennas, path selectable via power switching
Iris Solid State Power Amplifier (SSPA)	3 RF paths, dedicated to 3 antennas, path selectable via power switching (2W, 4W)
JPL Custom Antennas	
Low Gain Antenna (LGA)	7 dBi gain (Tx, Rx)
Medium Gain Antenna (MGA)	23 dBi gain (Tx)



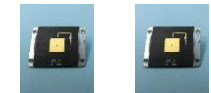
Iris Transponder



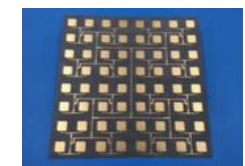
LNA



SSPA (2W, 4W)

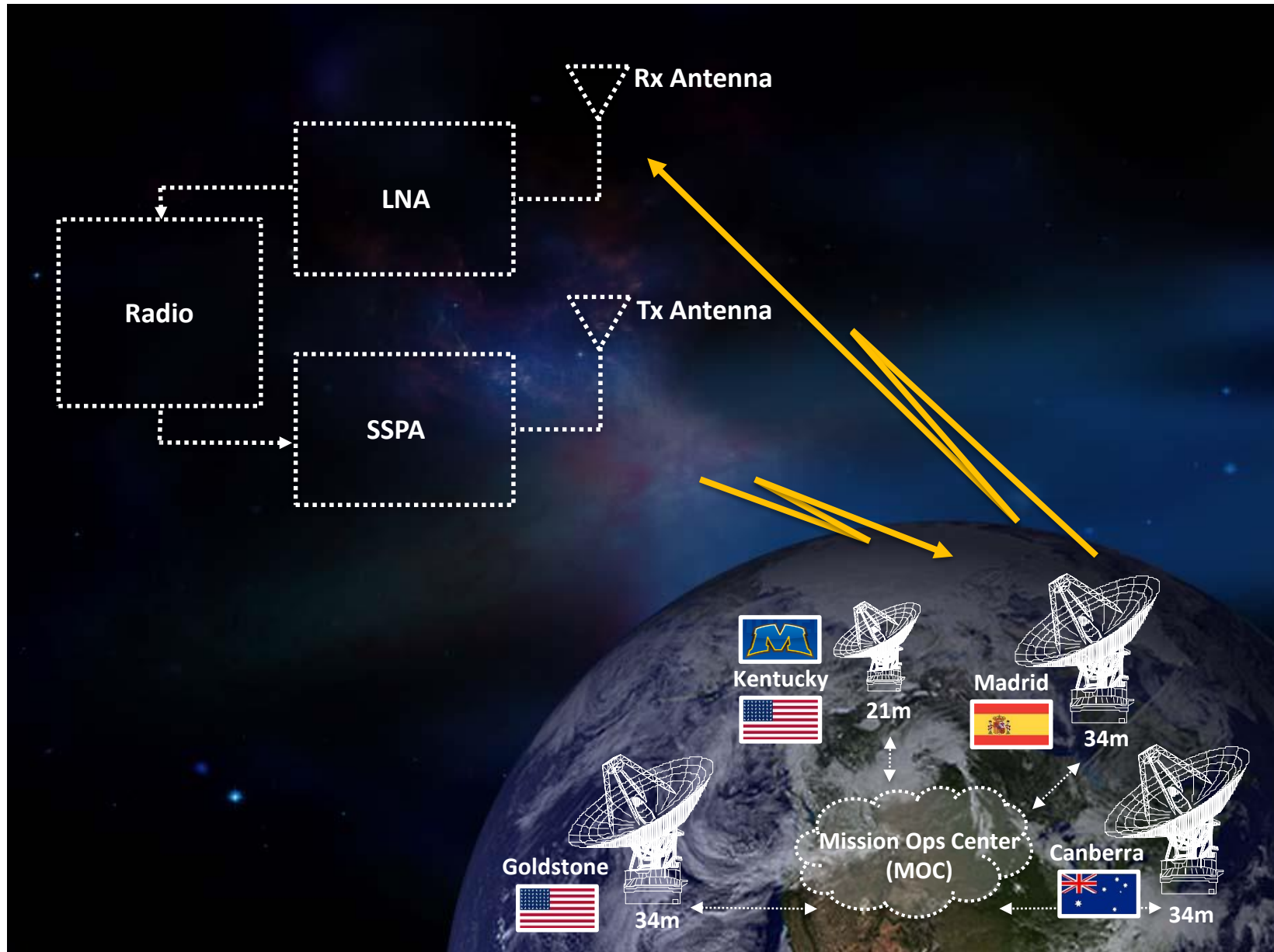


Tx LGA Rx LGA

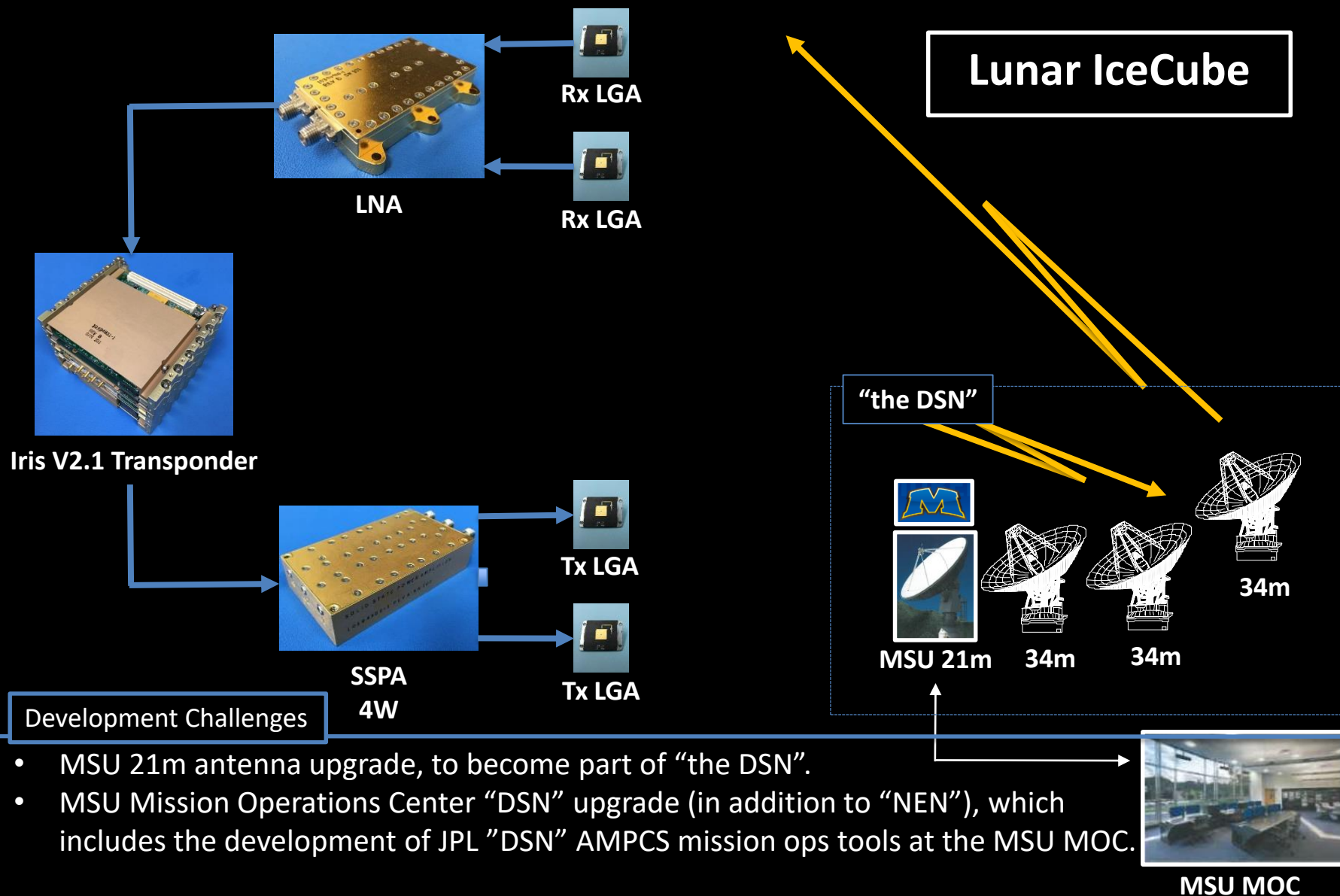


Tx MGA

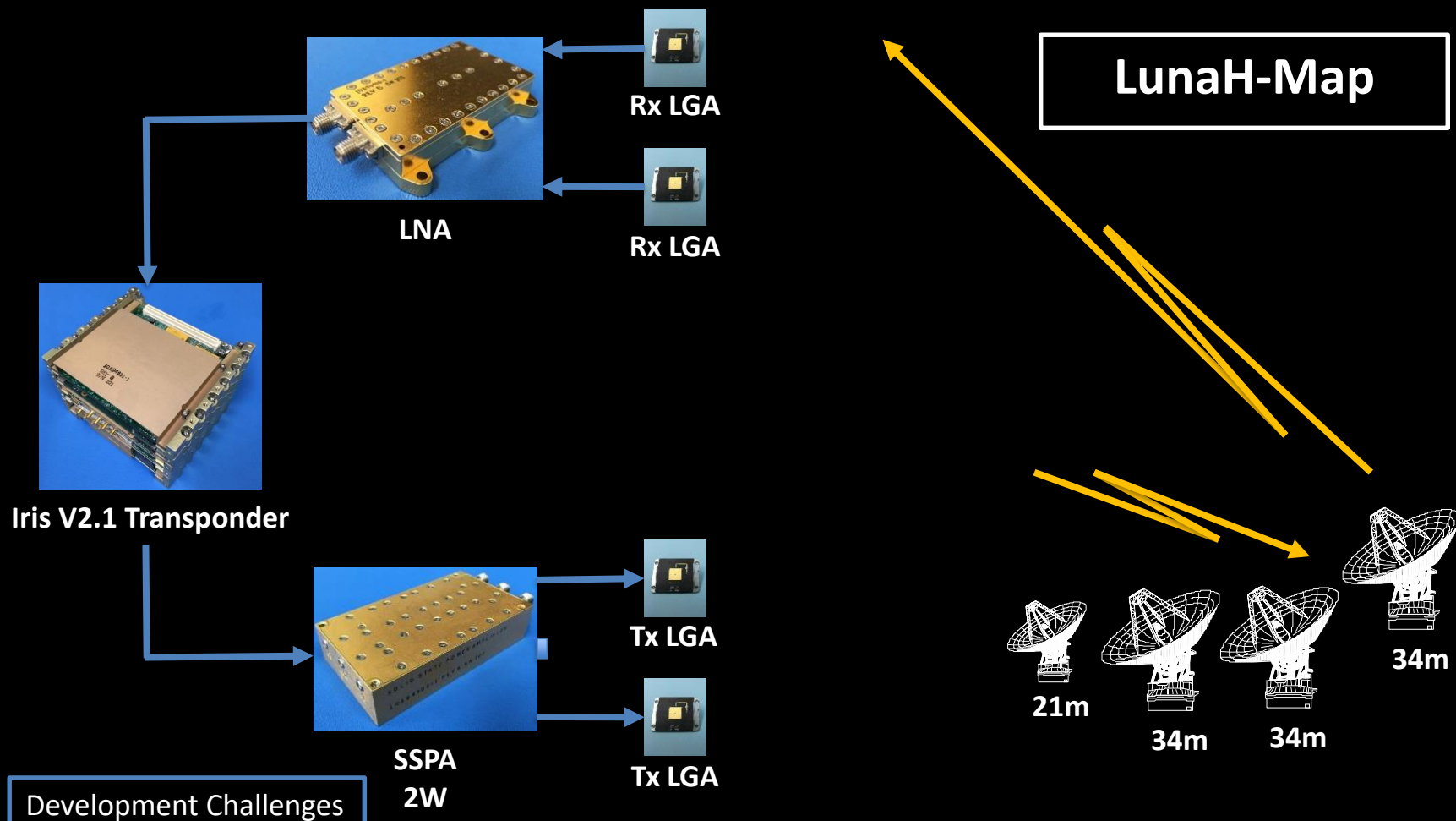
Telecom Systems End-to-End



Telecom Architecture & Development Challenges

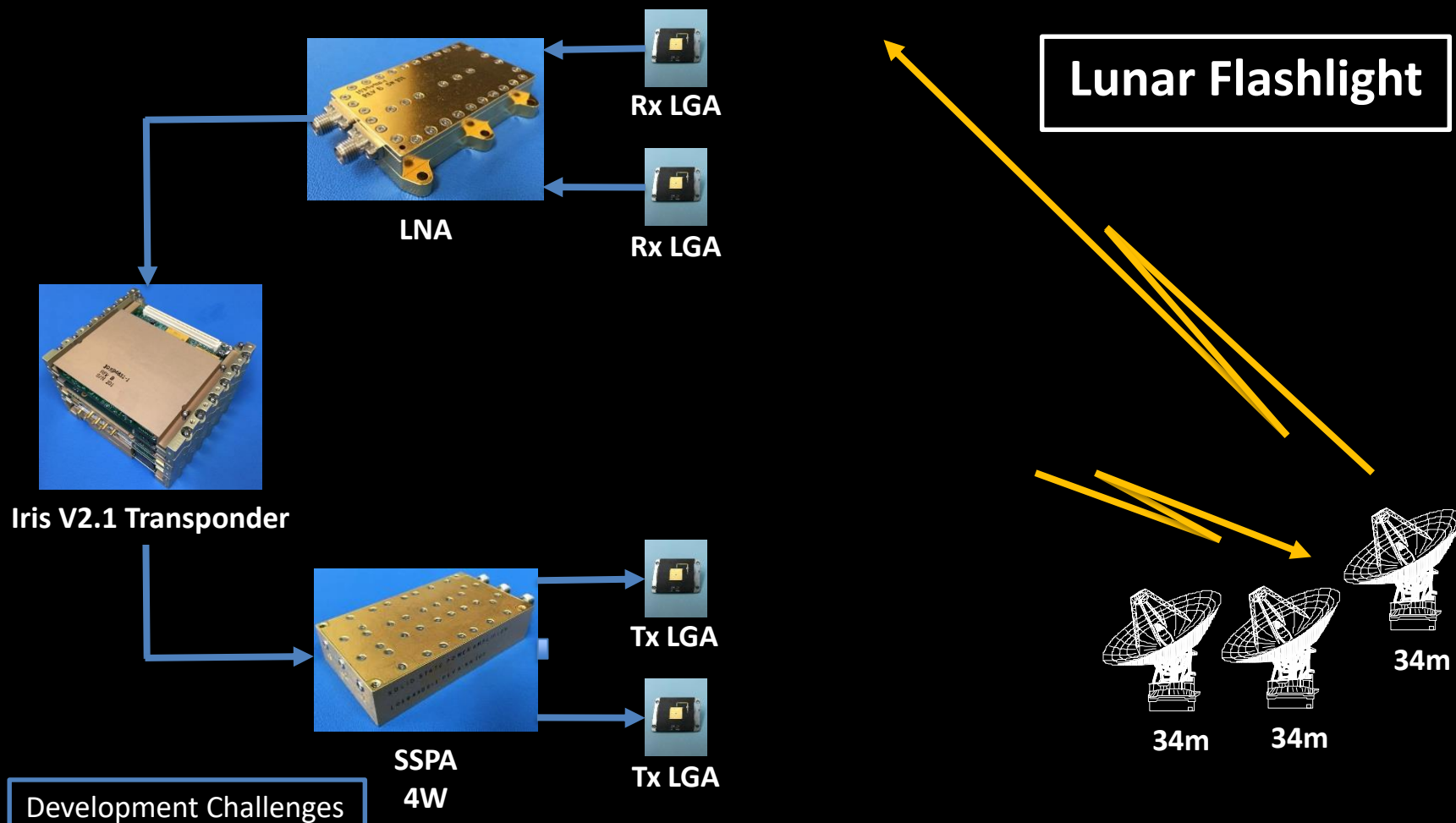


Telecom Architecture & Development Challenges



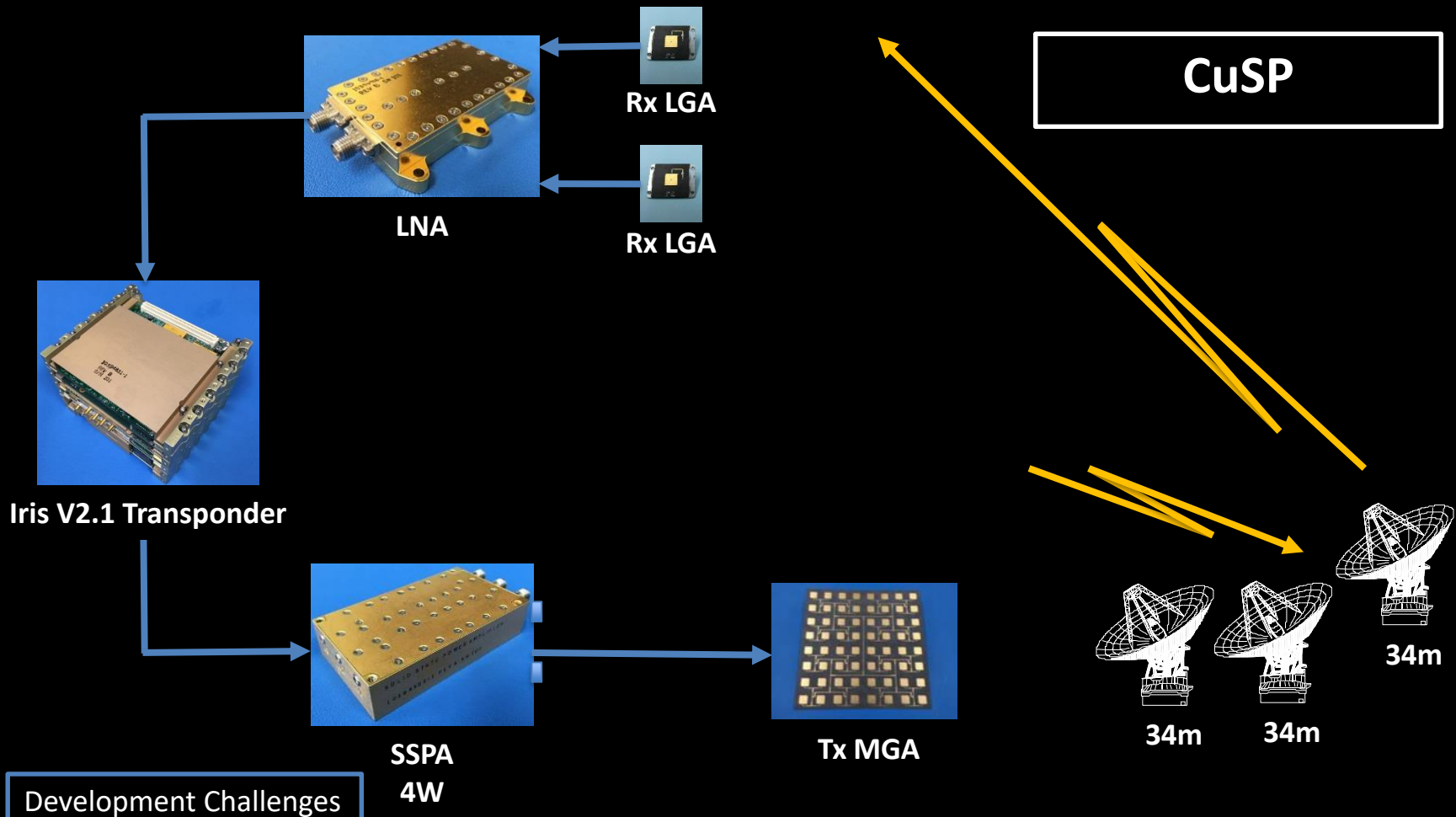
- Mission navigation requirement requires long comm. passes, hence the selection of 2W SSPA to keep power consumption low!

Telecom Architecture & Development Challenges



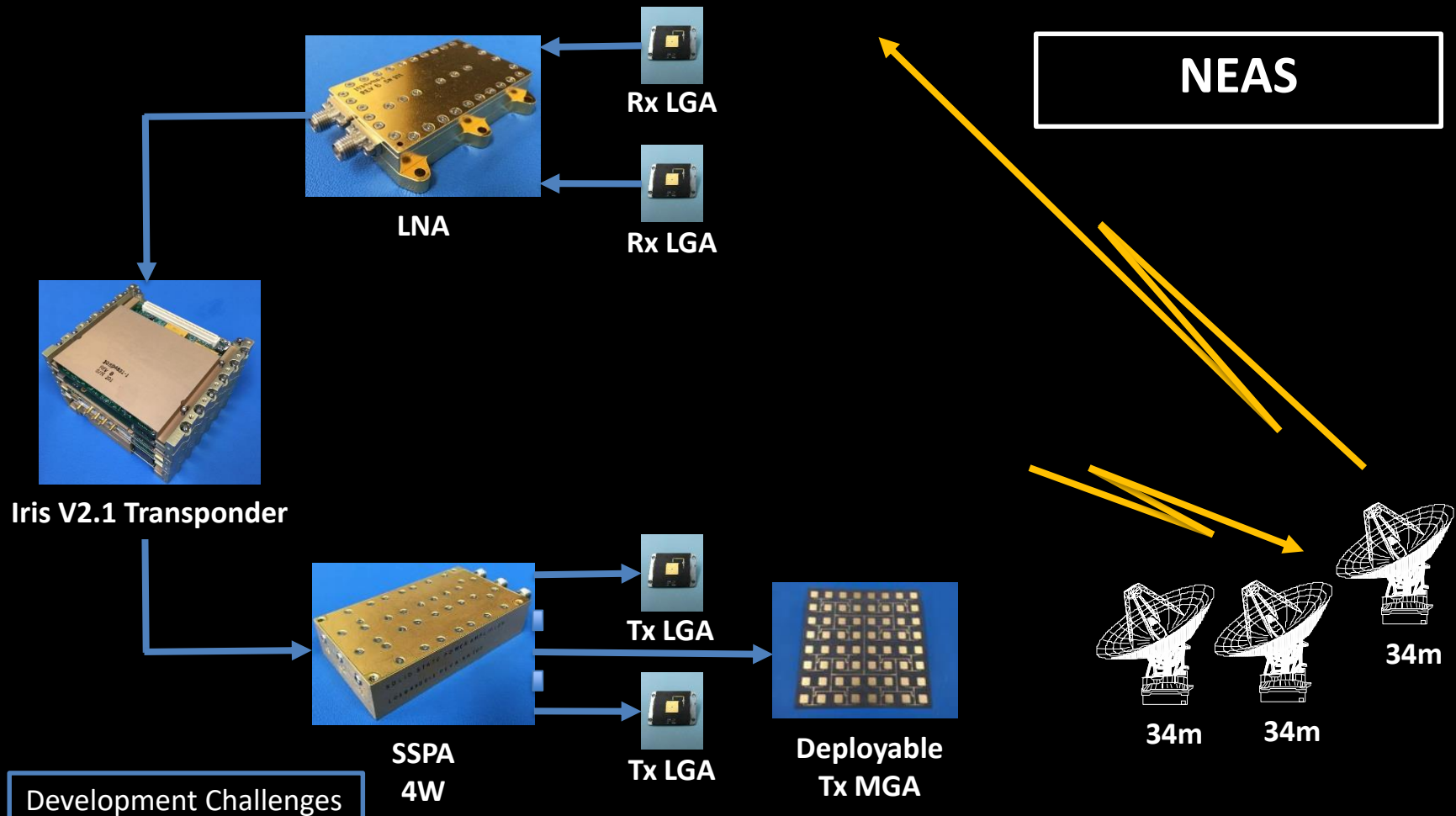
- Mission requirement to downlink data at high data rate.
- Requires special arrangements with Spectrum Management office, to select near Earth frequency (and telemetry coding) that minimizes potential interference to other near Earth missions. Reminder: near Earth traffic is more congested than Deep Space!

Telecom Architecture & Development Challenges



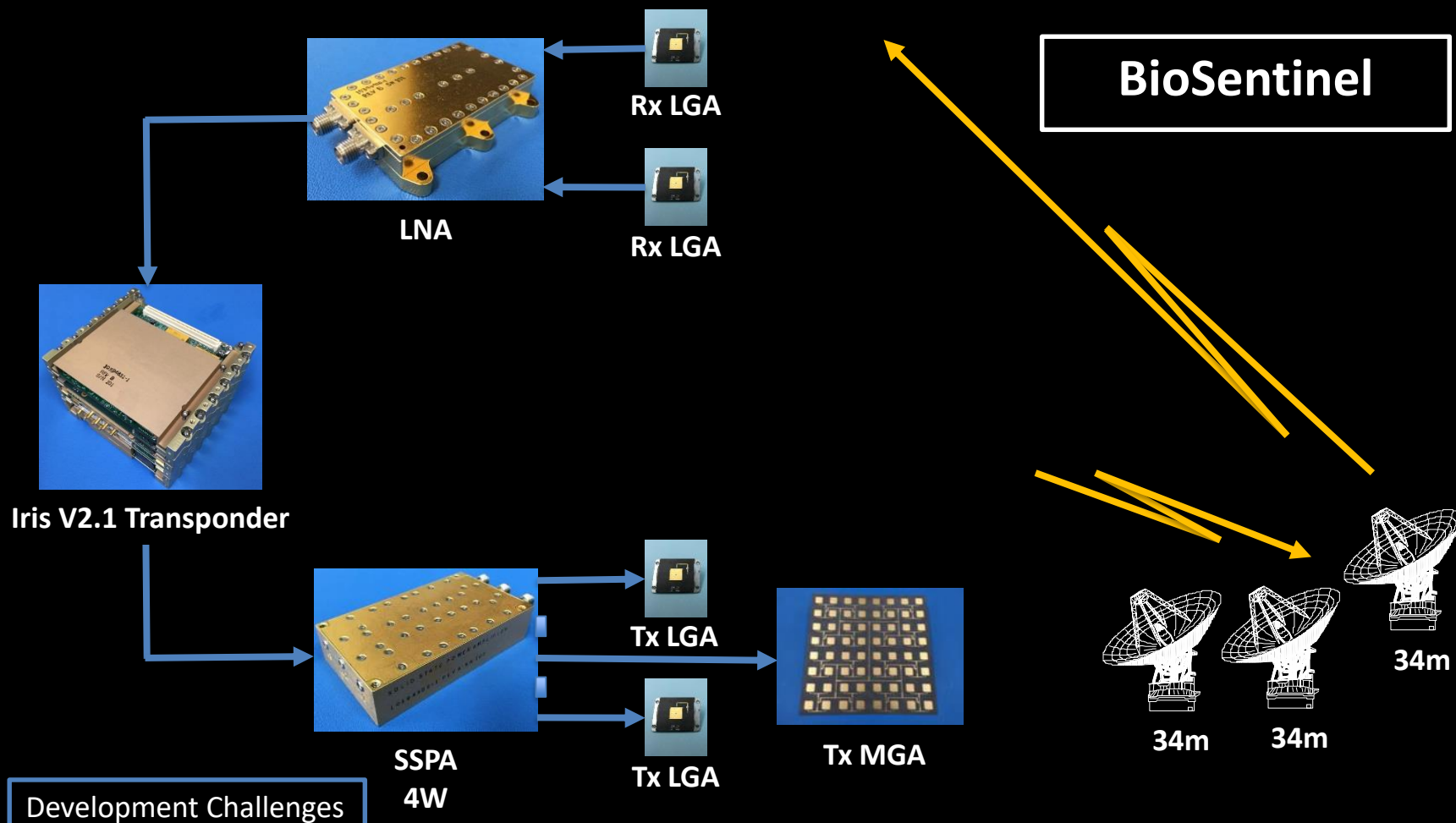
- Mission carries the risk of flying with only 1 transmit antenna.

Telecom Architecture & Development Challenges



- Mission deployable Tx MGA requires tight antenna pointing requirement!

Telecom Architecture & Development Challenges



- Include the typical mass, power, and volume constraints for a 6U CubeSat.

Telecom Architecture - Summary



	Mission Name	Radio	LNA	SSPA	Rx Antenna	Tx Antenna	DSN Ground Station
1	Lunar IceCube	Iris V2.1 Transponder	Iris LNA	Iris SSPA 4W	LGA (2)	LGA (2)	34m & 21m
2	LunaH-Map	Iris V2.1 Transponder	Iris LNA	Iris SSPA 2W	LGA (2)	LGA (2)	34m & 21m
3	Lunar Flashlight	Iris V2.1 Transponder	Iris LNA	Iris SSPA 4W	LGA (2)	LGA (2)	34m
4	CuSP	Iris V2.1 Transponder	Iris LNA	Iris SSPA 4W	LGA (2)	MGA (1)	34m
5	NEAS	Iris V2.1 Transponder	Iris LNA	Iris SSPA 4W	LGA (2)	LGA (2) Deployable MGA (1)	34m
6	Bio Sentinel	Iris V2.1 Transponder	Iris LNA	Iris SSPA 4W	LGA (2)	LGA (2) MGA (1)	34m

Summary: Telecom architectures for the above 6 EM1 CubeSats are uniform, with slight variations due to the specifics of the mission needs.

Telecom Parameters



	Mission Name	Destination	Max. Distance (km)	Network Compat.	UL/DL Freq. Band	Max. SC EIRP (dBm)	UL/CMD Data Rate (bps)	UL/CMD Coding	DL/TLM Data Rate (bps)	DL/TLM Coding
1	Lunar IceCube	Moon	~1M	DSN	X/X ^[1]	~42 ^[2]	62.5 - 1k	PCM/PSK/PM (16 kHz subcarrier)	62.5 - 256k	Turbo 1/2, 1/6 (25 kHz subcarrier, or direct carrier)
2	LunaH-Map	Moon	~1M	DSN	X/X ^[1]	~39 ^[3]	62.5 - 1k	PCM/PSK/PM (16 kHz subcarrier)	62.5 - 256k	Turbo 1/2, 1/6 (25 kHz subcarrier, or direct carrier)
3	Lunar Flashlight	Moon	~1M	DSN	X/X ^[1]	~42 ^[2]	62.5 - 1k	PCM/PSK/PM (16 kHz subcarrier)	62.5 - 256k	Turbo 1/2, 1/3, 1/6 (25 kHz subcarrier, or direct carrier)
4	CuSP	Helio Orbit	~15M	DSN	X/X	~59 ^[4]	62.5 - 1k	PCM/PSK/PM (16 kHz subcarrier)	62.5, 8k	Turbo 1/6 (25 kHz subcarrier, or direct carrier)
5	NEAS	Asteroid Belt	~179.5M	DSN	X/X	~59 ^[4]	62.5 - 1k	PCM/PSK/PM (16 kHz subcarrier)	62.5 - 8k	Turbo 1/6 (25 kHz subcarrier, or direct carrier)
6	Bio Sentinel	Helio Orbit	~105M	DSN	X/X	~59 ^[4]	62.5 - 2k	PCM/PSK/PM (16 kHz subcarrier)	62.5 - 8k	Turbo 1/2, 1/6 (25 kHz subcarrier, or direct carrier)

Summary: Telecom parameters for the above 6 EM1 CubeSats are uniform, with slight variations due to the specifics of the mission needs.

^[1] near Earth frequencies

^[2] with Tx LGA & 4W SSPA

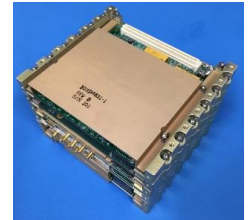
^[3] with Tx LGA & 2W SSPA

^[4] with Tx MGA & 4W SSPA

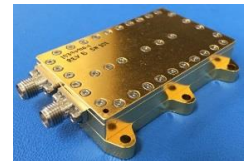
Closing Remarks



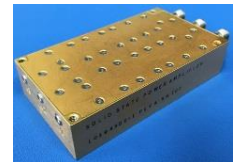
- This presentation shows the development of telecom systems for 6 interplanetary EM-1 CubeSat missions (Lunar IceCube, LunaH-Map, Lunar Flashlight, CuSP, NEAS, BioSentinel).
- The end-to-end telecom systems for the 6 EM-1 CubeSats are uniform with slight variations due to the specifics of the mission needs, and can be performed using the following:
 - Iris V2.1 Transponder, LNA, SSPA
 - JPL custom antennas
 - DSN ground station (34m, 21m) and the associated Mission Operations Center (MOC).
- We look forward to successful missions on EM-1!



Iris Transponder



LNA



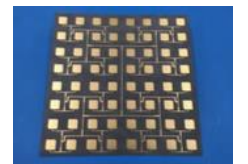
SSPA 2W, 4W



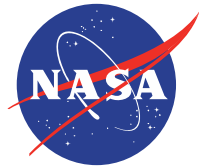
Tx LGA



Rx LGA



Tx MGA



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